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ABSTRACT

Crustal Evolution Education Project (CEEP) modules were designed to: (1) provide students with the methods and results of continuing investigations into the composition, history, and processes of the earth's crust and the application of this knowledge to man's activities and (2) to be used by teachers with little or no previous background in the modern theories of sea-floor spreading, continental drift, and plate tectonics. Each module consists of two booklets: a teacher's guide and student investigation. The teacher's guide contains all of the information present in the student investigation booklet as well as: (1) a general introduction; (2) prerequisite student background; (3) objectives; (4) list of required materials; (5) background information; (6) suggested approach; (7) procedure, including number of 45-minute class periods suggested; (8) summary questions (with answers); (9) extension activities; and (10) list of references. During the two-three recommended class periods, students determine rate of crustal plate movement during periods of geologic time, interpret areas representing flooding and draining of continents using a graph of sea level changes, determine effects of sea level change on evolution and extinction, and describe relative amount of stress and former environmental conditions that existed at the time sediments were deposited. (Author/JN)

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CRUSTAL EVOLUTION EDUCATION PROJECT

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Crustal Movement: A Major Force In Evolution

TEACHER'S GUIDE

Catalog No. 34W1003

For use with Student Investigation 34W1103
Class time: two to three 45-minute periods

Developed by
THE NATIONAL ASSOCIATION OF GEOLOGY TEACHERS

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NAGT Crustal Evolution Education Project

Edward C. Stoever, Jr., Project Director

Welcome to the exciting world of current research into the composition, history and processes of the earth's crust and the application of this knowledge to man's activities. The earth sciences are currently experiencing a dramatic revolution in our understanding of the way in which the earth works. CEEP modules are designed to bring into the classroom the methods and results of these continuing investigations. The Crustal Evolution Education Project began work in 1974 under the auspices of the National Association of Geology Teachers. CEEP materials have been developed by teams of science educators, classroom teachers, and scientists. Prior to publication, the materials were field tested by more than 200 teachers and over 12,000 students.

Current crustal evolution research is a breaking story that students are living through today. Teachers and students alike have a unique opportunity through CEEP modules to share in the unfolding of these educationally important and exciting advances. CEEP modules are designed to provide students with appealing firsthand investigative experiences with concepts which are at or close to the frontiers of scientific inquiry into plate tectonics. Furthermore, the CEEP modules are designed to be used by teachers with little or no previous background in the modern theories of sea-floor spreading, continental drift and plate tectonics.

We know that you will enjoy using CEEP modules in your classroom. Read on, and be prepared to experience a renewed enthusiasm for teaching as you learn more about the living earth in this and other CEEP modules.

About CEEP Modules...

Most CEEP modules consist of two booklets: a Teacher's Guide and a Student Investigation. The Teacher's Guide contains all the information and illustrations in the Student Investigation, plus sections printed in color, intended only for the teacher, as well as answers to the questions that are included in the Student Investigation. In some modules, there are illustrations that appear only in the Teacher's Guide, and these are designated by figure letters instead of the number sequence used in the Student Investigation.

For some modules, maps, rulers and other common classroom materials are needed, and in varying quantities according to the method of presentation. Read over the module before scheduling its use in class and refer to the list of MATERIALS in the module.

Each module is individual and self-contained in content, but some are divided into two or more parts for convenience. The recommended length of time for each module is indicated. Some modules require prerequisite knowledge of some aspects of basic earth science; this is noted in the Teacher's Guide.

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Crustal Movement: A Major Force In Evolution

INTRODUCTION

Fossils in rocks show that many different organisms lived in the geologic past. At times the fossils in rocks show that these organisms died out rather suddenly and were then replaced by new forms. What could have been the reason for such rapid changes?

Charles Darwin published a book *On The Origin Of Species* in 1859. This book explained Darwin's theory of how **evolution** occurred. The theory of evolution explains the stages and forms of development that animals and plants have gone through during geologic time. The **fossil record** supports the theory of evolution. The fossil record shows the remains or traces of once-living organisms found in sediments. However, the fossil record does not show how evolution works. Darwin said that evolution is caused by changes in the environment. When the environment changes, it puts stress on the organisms. Over a period of many generations the organisms either adapt to the change in the environment or die out. When *all* of one kind of organisms dies, it is called **extinction.**

In the fossil record, earth scientists can see periods of relatively rapid evolution, then periods of extinctions followed by rapid evolution. Such relatively rapid changes in the fossil record present a problem. No one knows the reason for these changes. Such things as river floods, volcanic eruptions or earthquakes are too local and short-lived to be the cause. There must be a much greater or even worldwide force for evolutionary change. What can that force be?

PREREQUISITE STUDENT BACKGROUND

An understanding of the influence that the lengthening and swelling of the mid-ocean ridge has upon sea level fluctuations is an essential prerequisite for this activity. The module, *Why Does Sea Level Change?*, would be helpful prior to this module. Graph interpretation, division and conversion of metric units are essential skills for the activities.

OBJECTIVES

After you have completed these activities, you should be able to:

1. Determine the rate of crustal plate movement during periods of geologic time.

2. Interpret areas that represent flooding and draining of continents, using a graph of sea level changes.

3. Determine the effects of sea level change on evolution and extinction.

4. Describe the relative amount of stress and former environmental conditions that existed at the time the sediments were deposited, using a model "rock column."

MATERIALS

Metric rulers

BACKGROUND INFORMATION

Fossils, the preserved remains or traces of animals or plants, have revealed much about:

a. the age of the sediments and rocks that contain them.

b. the succession of life development (evolution that animals and plants have gone through during geologic time).

c. changes in the type of environment and geographic setting through geologic time.

Since the publication of Charles Darwin's *On The Origin Of Species* in 1859, the theory of evolution has gained general acceptance among scientists and is supported by the fossil record. However, the fossil record does not show how evolution works. Darwin said that evolution is caused by the physical, chemical and biological factors of the environment or "natural selective forces." When the environment places stress on a group (e.g., species) of organisms, they must eventually adapt to the changes in the environment or their kind will become extinct.

Plate Tectonics and the Cretaceous Period: The theory of plate tectonics, developed from ideas of continental drift published by Alfred Wegener in 1915, states that the outermost spherical shell of the earth is made up of about a dozen rigid plates. Some of these plates bear continents. The surface of the earth is changed when these plates move. Plates are created by magma rising from the mantle of the earth upward to the mid-ocean ridges. Here the magma spreads away from the ridges, cools off and becomes solid and rigid. The plate edges become reabsorbed during subduction in deep sea trenches. For the past 200 million years, ocean basins have been created repeatedly by the process of sea-floor spreading, where plates separate. The sea-floor spreading and consequent widening of the Atlantic Ocean were not one single continuous event but irregular pulsations.

During times of rapid plate movement, the mid-ocean ridges swell outward, which causes a rise in sea level. During times of little or no plate movement, the ocean ridges contract and a lowering of sea level results. Swelling ocean ridges have the same effect on the ocean as a rock placed in a glass of water. They cause the ocean level to rise just as the rock causes the water level to rise in the glass. Alternating with periods of rapid sea-floor spreading, or plate movements, were quiet periods when plate movements slowed or stopped. This quiet period allowed the ocean ridges to contract, causing the sea level to lower. This had the same effect as taking the rock out of the glass of water, which lowers the water level in the glass. In the Cretaceous there were at least nine periods of rapid sea-floor spreading accompanied by rapid rises in the sea level. This was followed by quiet periods of plate movements causing the sea level to fall. Many scientists believe the sea level may have changed as much as 500 meters several times during the past 200 million years. At times extensive areas of what is now the United States were under sea water. Even the Appalachian Mountain area might have been covered by the sea.

These movements in the earth's crust are now believed to cause massive changes in the earth's environment. These changes strongly affect the evolutionary history of organisms. Plate tectonics could well be a universal force that explains the different rates of evolution. Evidence of a direct connection between plate tectonics history and major evolutionary events can be seen in Cretaceous rocks. The Cretaceous Period, which lasted 70 million years, was a time of active plate movement and rapid evolution, during which there were abrupt appearances and extinction of organisms. From evidence based on times of rapid reversals in the earth's magnetic field, the history of the Atlantic Ocean is revealed. In the early part of the Cretaceous, 135–100 million years ago (m.y.a.), the northern and central part of the Atlantic Ocean was narrowly open, but the ocean was still closed to the south between Africa and South America. In the middle and late part of the Cretaceous, 100–65 m.y.a., there was widespread and periodically rapid sea-floor spreading at the Mid-Atlantic Ridge. This is the boundary between the Eurasian and American plates. The Atlantic Ocean was broadened to nearly 75 percent of its present size, and the southern part of the Atlantic Ocean was formed between Africa and South America during this period.

SUGGESTED APPROACH

This activity provides an opportunity for students to examine some of the implications of sea-level change caused by crustal movement. It is essential that students have an understanding of the concepts developed in the module, *Why Does Sea Level Change?*. It is suggested that this module be supplementary or excursionary for the more able students or classes. Students should work independently or in small groups on this activity; independent analysis and interpretation of data should be encouraged. In order that students can understand for themselves the basic mathematics required in Worksheet 1, you should avoid providing too much instruction for completing the Worksheet. However, you should monitor closely the procedures students are using in order to provide assistance if difficulties arise in metric unit conversions (last column).

Actual data is used for Worksheets 2 and 3. When the extinction lines and origin lines are drawn upward to the sea level graph, the lines are not 100% related to sea level rise and fall. Rather, a *tendency* exists for the extinction and origin lines to occur in certain positions. The point is that scientific data generally *suggests* things, rather than proves things. This should be brought out in a post-lab discussion.

It is a relatively recent concept that environmental stress is caused by changes in sea level. In this way, sea level changes influence the evolution of organisms. It is important to tell students that many aspects of this concept are being further refined through new information similar to that presented in the activity. This is the self-revising aspect of science and the fundamental reason why scientists are always seeking new information and new understandings. Theories and new ideas provide a place to begin and are vital to the total journey of knowledge.

PROCEDURE

PART A: How fast do ocean plates move?

In this part students determine the amount of crustal plate movement that has occurred during seven intervals of geologic time. This movement is related to sea level changes during the Cretaceous Period. Rising and falling of sea level cause flooding and draining of continents.

Key words: evolution, fossil record, extinction

Time required: one 45-minute period

Materials: metric rulers

In a previous activity you may have learned how the rate of sea-floor spreading is believed to affect sea level. During times of rapid plate movement, the mid-ocean ridges swell upward and outward, causing a rise in sea level. In times of little or no plate movement, the ocean ridges sink and sea level falls.

By determining the age of sediments, scientists have been able to measure the distance plates have moved during various periods of geologic time.

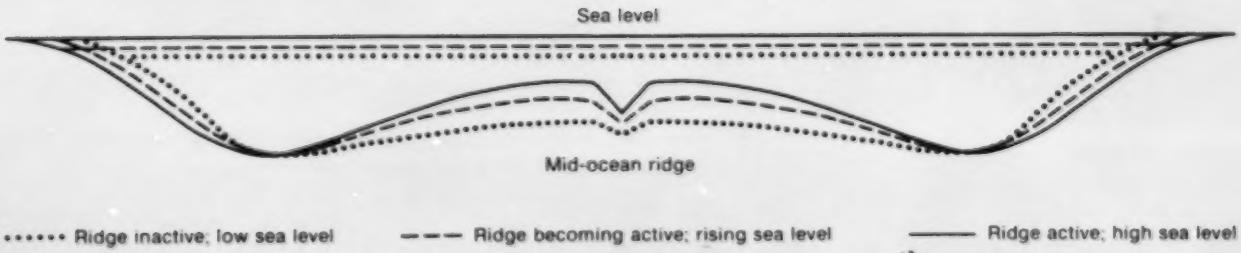

Sea level
Mid-ocean ridge
Ridge inactive; low sea level
Ridge becoming active; rising sea level
Ridge active; high sea level

Figure 1. Swelling along the mid-ocean ridge causes a rise in sea level.

1. Figure 2 shows the distance the North American plate and the African and Eurasian plates spread apart during the past seven intervals of geologic time. Complete Worksheet 1 to determine what interval of time had the most active plate movement. Metric rulers must be used on Figure 2; 1 cm = 1000 km.

Note: The calculations completed in the table are only approximations. The map scale is such that a high degree of variability in answers can be expected. The general trend and calculations by which movement/year is determined are the important aspects of this activity.

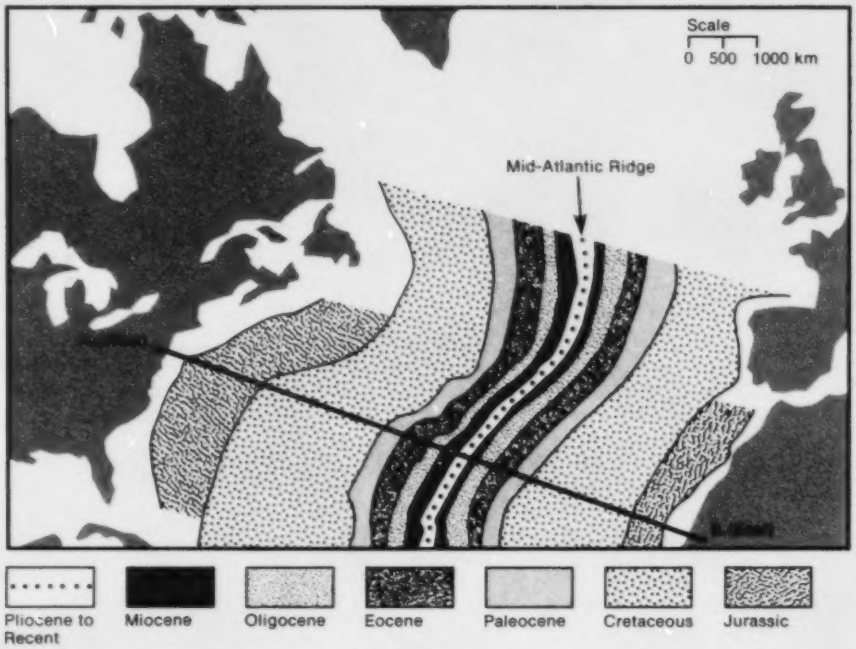


Figure 2. Map showing the distances crustal plates have moved away from the Mid-Atlantic Ridge during the past 190 million years. (Modified from Lamont-Doherty Geological Observatory, Columbia University, 1974.)

Answer Sheet 1 (PART A)

Youngest

Oldest

Rate of Movement of Crustal Plates Along the Mid-Atlantic Ridge

Column No. 1	2	3	4	5	6	7
Geologic time interval	Duration of geologic time interval in millions of years (from col. 1)	Amount of movement measured along line A–B during geologic time intervals			Average rate of movement in a *million* years: col. 5 ÷ col. 2	Average rate of movement in *one* year Remember: 1 km = 100,000 cm
		West of ridge	East of ridge	Average: col. 3 + 4 ÷ 2		
Pliocene to Recent 0–5 m.y.a.	5 m.y.	100 km	100 km	100 km	20 km/m.y.	2.00 cm/yr
Miocene 5–23 m.y.a.	18 m.y.	**200 km**	**130 km**	**165 km**	**9.2** km/m.y.	**.92** cm/yr
Oligocene 23–38 m.y.a.	15 m.y.	**250 km**	**250 km**	**250 km**	**16.7** km/m.y.	**1.67** cm/yr
Eocene 38–53 m.y.a.	**15** m.y.	**380 km**	**300 km**	**340 km**	**22.7** km/m.y.	**2.27** cm/yr
Paleocene 53–65 m.y.a.	**12** m.y.	**300 km**	**250 km**	**275 km**	**22.9** km/m.y.	**2.29** cm/yr
Cretaceous 65–135 m.y.a.	**70** m.y.	**1900 km**	**1600 km**	**1750 km**	**25** km/m.y.	**2.50** cm/yr
Jurassic 135–180 m.y.a.	**45** m.y.	**1160 km**	**500 km**	**830 km**	**18.4** km/m.y.	**1.84** cm/yr

2. During what interval of geologic time did the Atlantic Ocean begin to open?

The Atlantic Ocean can be interpreted to have opened during the oldest time interval shown in Figure 2, the Jurassic Period (180–135 m.y.a.). This is because these are the oldest rocks to be found on the ocean bottom, and these rocks occur along both continental margins.

3. During which of the intervals of geologic time was the slowest plate movement?

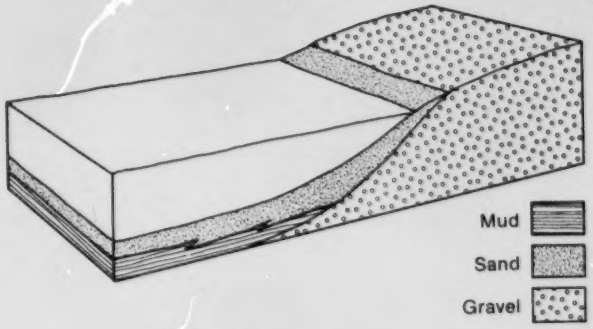
In the Miocene there was an average movement of less than 1 cm/yr.

4. During which of the intervals of geologic time was the fastest plate movement?

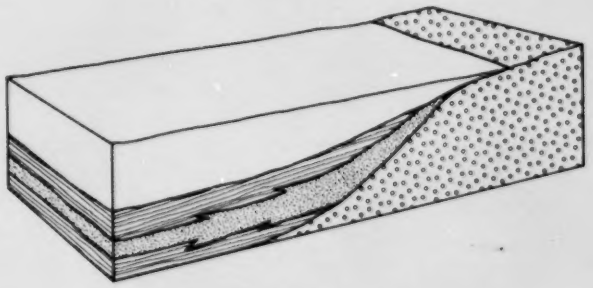
The Cretaceous Period; an average movement of 2.5 cm/yr.

As you have seen, the Cretaceous Period was a time of active plate movement. This movement was not always continuous and steady but occurred in "spurts". There were times of rapid plate spreading and ocean ridge building and swelling. There were also quiet times when plate movement slowed and ocean ridges contracted. Geologists have identified at least nine major rises and falls of sea level by studying ocean sedimentation patterns that occurred during the Cretaceous Period.

5. Look at the graph in Figure 4. Write the word "rising" on the graph where the line shows sea level rising. Write the word "falling" on the graph where the line shows sea level falling.



a. Low sea level



b. High sea level

Figure 3. Sedimentation pattern for high and low sea level today.

6. Did the sea level rise or fall during times of rapid plate movement?

The sea level rose.

7. Did the sea level rise or fall during times of slow plate movement?

The sea level fell.

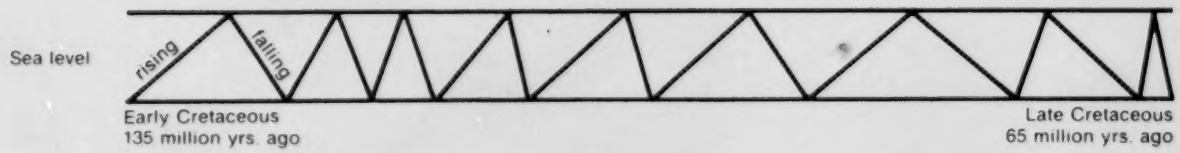


Figure 4. Graph shows the rise and fall of sea level during the Cretaceous Period.

PROCEDURE

PART B: How does the change in sea level affect the organisms?

Students are exposed to the idea of how changes in sea level relate to environmental stress. Extinction and origin data obtained from Cretaceous cephalopods are analyzed in relation to sea level changes. The students then interpret a stratigraphic column for changes in sea level and environmental stress.

Key words: environmental stress, cephalopods, origin curve, extinction curve

Time required: one 45-minute period

Materials: metric ruler

You have seen how movement of the crustal plates away from the ocean ridges is believed to have caused changes in sea level. Not only was the appearance of the earth's surface affected, but sea level shifts also caused great changes in world climates.

During times of higher sea levels, coastal plains and inland depressions became shallow seas. Changes in the seasons became more moderate. Higher sea levels produced a more uniform, warm and moist climate. (See Figure 5.)

Lower sea levels drained coastal and inland seas. More land area was exposed and there were changes in ocean currents which distribute heat around the world. A cooler and drier climate resulted. (See Figure 5.)

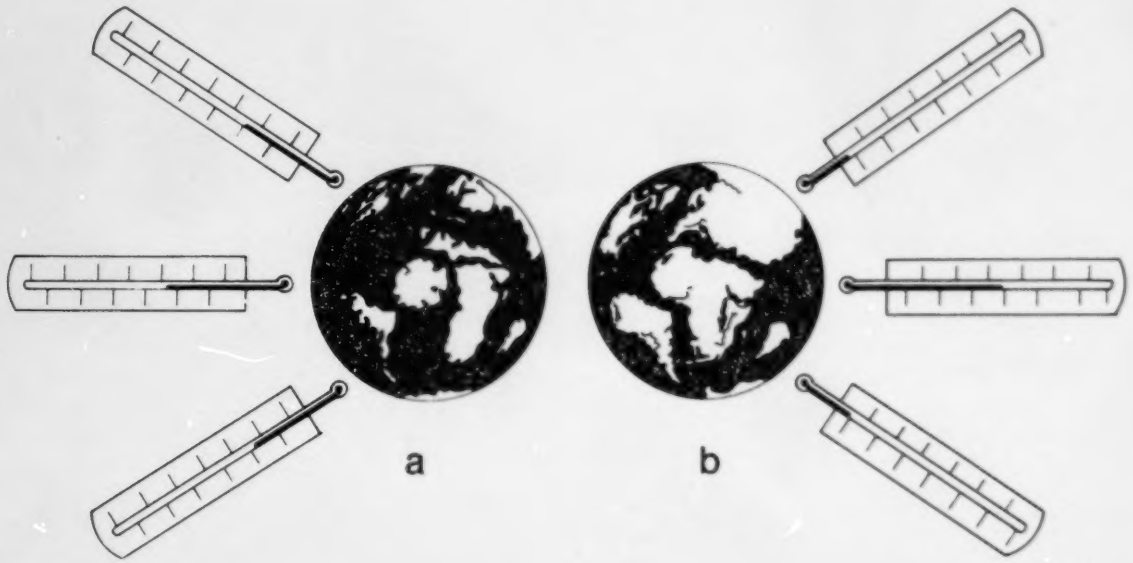
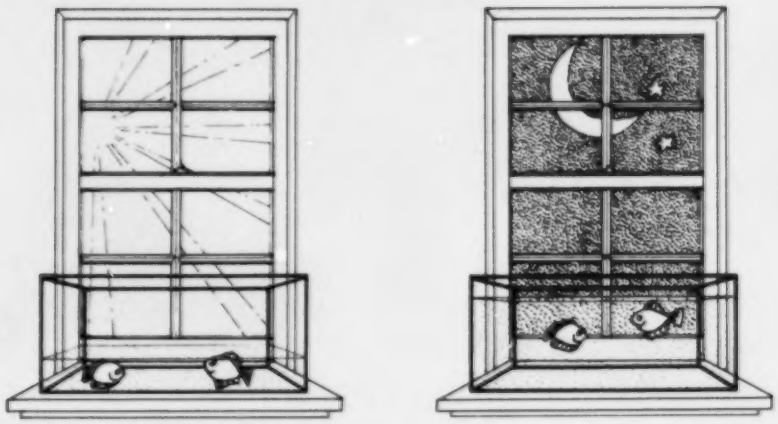


Figure 5. Changes in the sea level can (a) flood or (b) drain the continents, creating moderate or extreme climates.

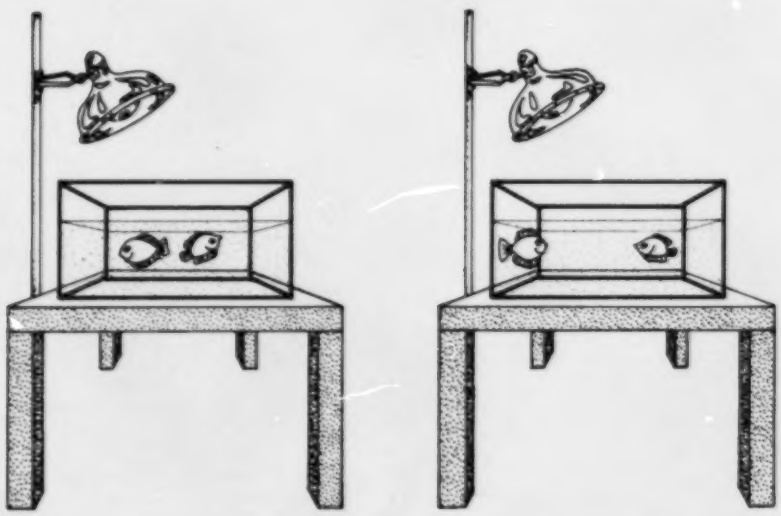
Changes in sea level and climate caused stress on the organisms that lived in the oceans. To help understand the idea of **environmental stress,** think of the following situation:

You have two fish tanks. One fish tank you keep on a window ledge. The water gets quite warm during the day when the sun is shining in, and it gets cool at night because it is close to the window. Also, you allow the water level to get very low, and then you fill the tank to the top. You are allowing the water level to change constantly. (See Figure 6.)

The other fish tank you keep in the center of the room. It always gets the same amount of light, and it stays at a comfortable room temperature throughout the year. You are careful not to allow too much water to evaporate before you bring it back up to level. (See Figure 6.)



a. Changeable conditions.



b. Constant conditions.

Figure 6. Environmental conditions

1. Which tank involves more stress on the organisms?

The tank in Figure 6a will involve more stress on the organisms. The environment would go from shallow, warm water to deep, cold water.

2. Which tank will have the more stable environment?

The tank in Figure 6b will have the more stable environment. With a consistent depth and light source, the water environment would have a stable temperature.

Recent studies have shown that there is a link between evolution and environmental stability.

Cephalopods (sef'-uh-la-pahds) are marine organisms that were common in the ocean during the Cretaceous Period. See Figure 7. The graph in Worksheet 2 shows the number of cephalopod groups that came into existence during the Cretaceous Period. This graph is called an **origin curve.** The drawing at the top of this graph shows how the sea level was changing during this time.

Draw a straight line from each peak marked "O" on the origin graph upward to the sea level line. (Make certain that your straight lines are parallel to the first solid line that has already been drawn.)

3. When do most of the peaks in the origin curve occur, during sea level *rise* or sea level *fall?*

Origin curve peaks show a preference for intervals of sea level rise or flooding. Of the ten origin peaks, six occur during times of maximum or rising sea level.

The graph in Worksheet 3 shows the number of cephalopod groups that became extinct during the Cretaceous Period. This graph is called an **extinction curve.** Draw a line from each peak marked "X" on the extinction curve upward to the sea level line. Again, make certain that these lines are parallel to the first line that has been drawn.

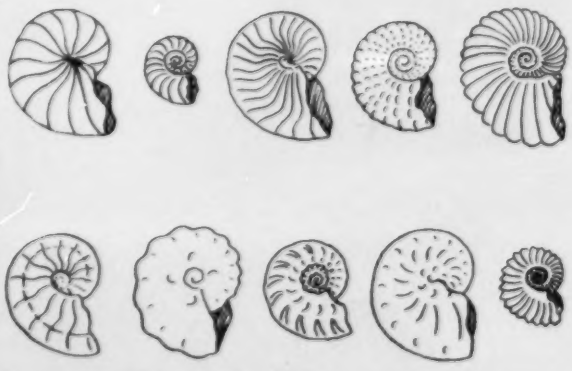


Figure 7. Cephalopod shells

4. Do most of the peaks in the extinction curve occur during sea level rise or sea level fall?

Extinction curve peaks show a preference for times of sea level fall or draining. Of the eight extinction curve peaks, six show a tendency to be located at times of falling sea level. Three occur very close to the time of maximum recession.

5. How do you think the origin and extinction of the cephalopods are related to sea level changes? (Spend some time thinking of all possibilities.)

The cephalopods lived on the continental shelves and moved into the interior lowlands as the ocean expanded. Conversely, both evolutionary rates and extinctions increase as the environmental stresses increase during periods of sea level fall. The number and size of marine habitats decrease as the competition for food and living space increases. The climates become more variable and many kinds of organisms die.

Many of the evolutionary events during the Cretaceous can be directly related to plate tectonics. The same can probably be said about other geologic time periods.

During sea level rise, the rates of evolution are slow, but the size and diversity of marine populations gradually increase. Environmental stresses are few, and the forces of natural selection are low. This is because the climate becomes generally warmer and less seasonal over the entire globe. There is also more ocean space in which the marine organisms can exist.

Worksheet 4 shows a model of a column of sediment that was deposited during the Cretaceous Period. The oldest layer is at the bottom; the youngest layer is at the top.

From the fossils and the type of sediment, you can tell much about the environment during the time the sediments were deposited.

6. From what you have learned in this activity, label each sediment unit on Worksheet 4 as representing sediment deposited during either rising or falling sea level. Start at the bottom unit, A, and work upward to E. (Also see Figure 3.)

See Answer Sheet 4.

7. From what you have learned in this activity, label each sediment unit as showing a period of either high or low environmental stress for the organisms.

Note that units B and D were times of transition.

8. Which sediment units show increasing rate of extinction?

Going from units A through E, extinction increased during deposit of units B and C.

9. Which sediment units show increasing rate of evolution?

Going from units A through E, evolution increased during deposit of units C and E.

SUMMARY QUESTIONS

1. Explain how sea level changes can be caused by crustal movement.

Movement of crustal plates away from an ocean ridge is not always constant. At times the movement is relatively rapid, and at other times the movement is relatively slow. During times of more rapid plate movement, the mid-ocean ridge swells outward, raising sea level several hundred meters.

2. Explain how changes in sea level can affect worldwide climatic conditions.

During times of higher sea levels, large portions of the continents are flooded. Changes in the seasons are more moderate and uniform; warm moist climates prevail. Lower sea levels drain large portions of the continents and there are changes in the ocean currents which distribute heat around the world. A cooler, drier climate is produced.

3. Explain how crustal movement could be a worldwide force for evolutionary change.

Crustal movement influences sea level. When crustal movement is relatively rapid, sea level is high; when crustal movement is slow, sea level is lower. This in turn has an influence on worldwide climatic conditions, which in turn create high or low environmental stress on organisms. During initial intervals of high environmental stress (lowering of sea level), many kinds of marine organisms become extinct. On the other hand, during periods of low environmental stress (high sea level) many new kinds of marine organisms come into existence.

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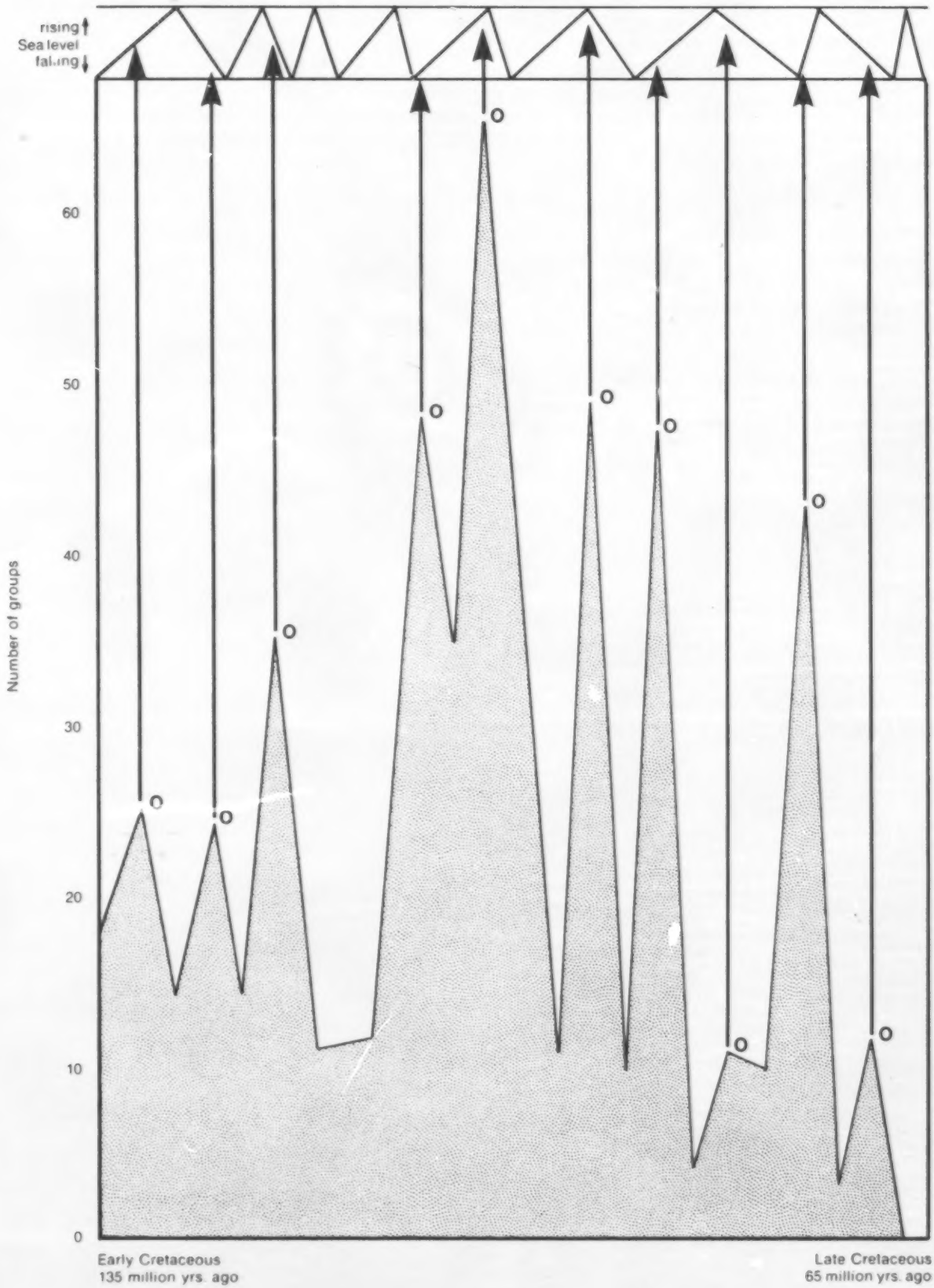
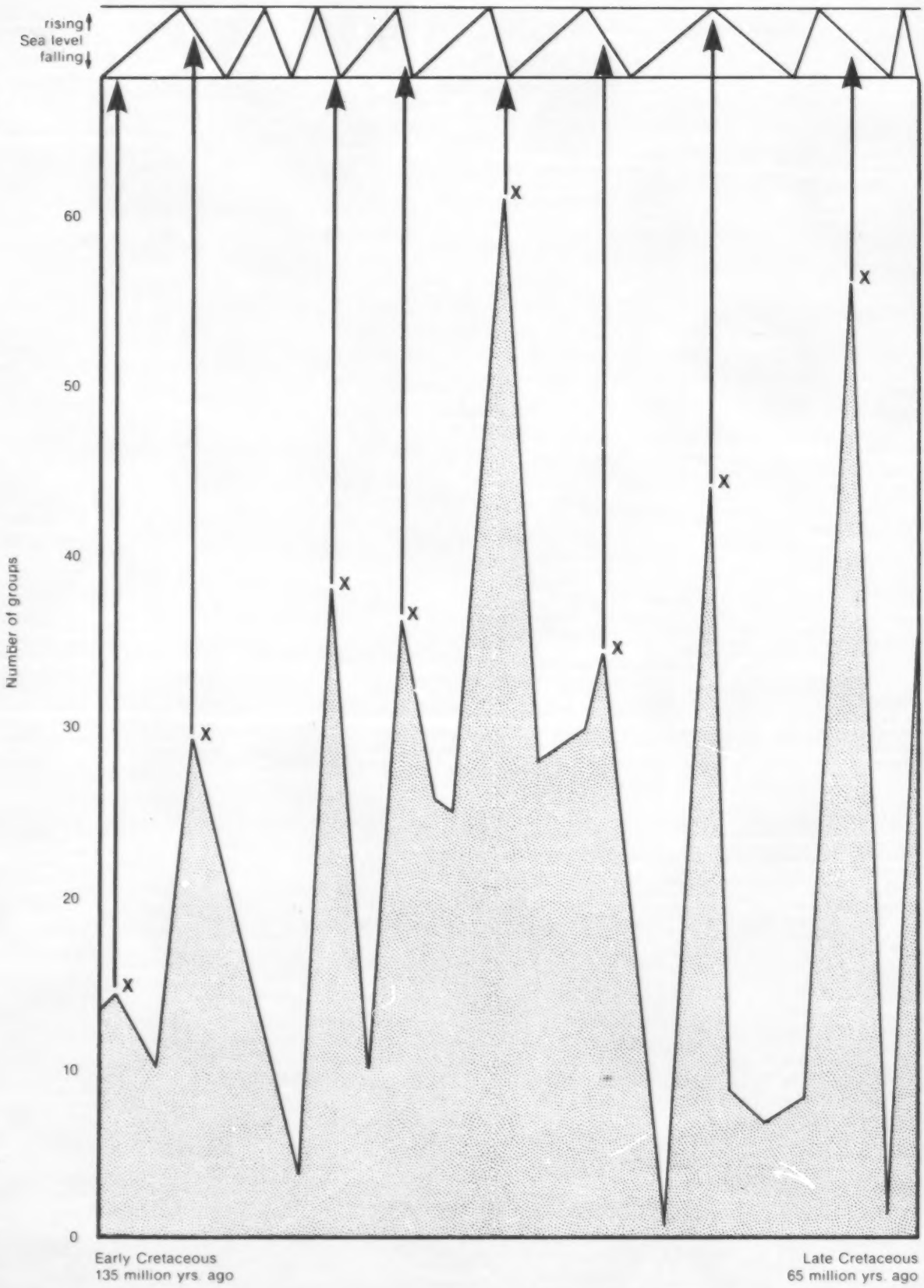
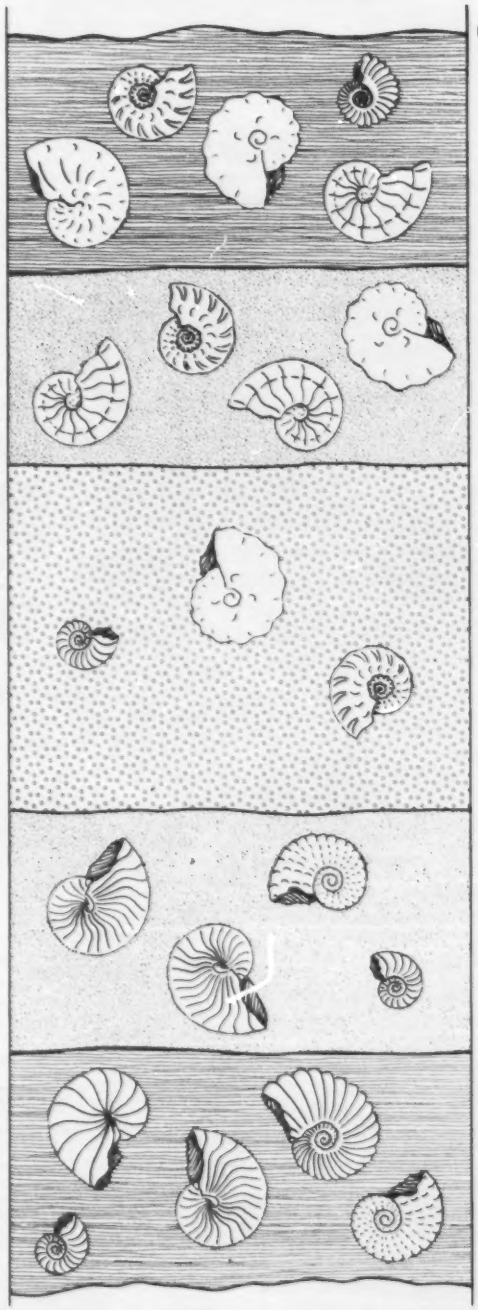


This origin curve graph shows the number of cephalopod groups that came into existence during the Cretaceous Period. The line graph at the top shows the sea level changes during this time. (Modified from Kaufman, 1976.)



This extinction curve graph shows the number of cephalopod groups that became extinct during the Cretaceous Period. The line graph at the top shows the sea level changes during this time. (Modified from Kaufman, 1976.)



Unit	Rising sea level or falling sea level (Start at unit A)	High environmental stress or low environmental stress
E	rising	low
D	rising	(changing?)
C	falling	high
B	falling	(changing?)
A		

Key

Mud Sand Gravel

15

Answer Sheet 4 (PART B)

NAGT Crustal Evolution Education Project Modules

CEEP Modules are listed here in alphabetical order. Each Module is designed for use in the number of class periods indicated. For suggested sequences of CEEP Modules to cover specific topics and for correlation of CEEP Modules to standard earth science textbooks, consult Ward's descriptive literature on CEEP. The Catalog Numbers shown here refer to the CLASS PACK of each Module consisting of a Teacher's Guide and 30 copies of the Student Investigation. See Ward's descriptive literature for alternate order quantities.

CEEP Module	Class Periods	CLASS PACK Catalog No.
• A Sea-floor Mystery: Mapping Polarity Reversals	3	34 W 1201
• Continents And Ocean Basins: Floaters And Sinkers	3-5	34 W 1202
• Crustal Movement: A Major Force In Evolution	2-3	34 W 1203
• Deep Sea Trenches And Radioactive Waste	1	34 W 1204
• Drifting Continents And Magnetic Fields	3	34 W 1205
• Drifting Continents And Wandering Poles	4	34 W 1206
• Earthquakes And Plate Boundaries	2	34 W 1207
• Fossils As Clues To Ancient Continents	2-3	34 W 1208
• Hot Spots In The Earth's Crust	3	34 W 1209
• How Do Continents Split Apart?	2	34 W 1210
• How Do Scientists Decide Which Is The Better Theory?	2	34 W 1211
• How Does Heat Flow Vary In The Ocean Floor?	2	34 W 1212
• How Fast Is The Ocean Floor Moving?	2-3	34 W 1213
• Iceland: The Case Of The Splitting Personality	3	34 W 1214
• Imaginary Continents: A Geological Puzzle	2	34 W 1215
• Introduction To Lithospheric Plate Boundaries	1-2	34 W 1216
• Lithospheric Plates And Ocean Basin Topography	2	34 W 1217
• Locating Active Plate Boundaries By Earthquake Data	2-3	34 W 1218
• Measuring Continental Drift: The Laser Ranging Experiment	2	34 W 1219
• Microfossils, Sediments And Sea-floor Spreading	4	34 W 1220
• Movement Of The Pacific Ocean Floor	2	34 W 1221
• Plate Boundaries And Earthquake Predictions	2	34 W 1222
• Plotting The Shape Of The Ocean Floor	2-3	34 W 1223
• Quake Estate (board game)	3	34 W 1224
• Spreading Sea Floors And Fractured Ridges	2	34 W 1225
• The Rise And Fall Of The Bering Land Bridge	2	34 W 1227
• Tropics In Antarctica?	2	34 W 1228
• Volcanoes: Where And Why?	2	34 W 1229
• What Happens When Continents Collide?	2	34 W 1230
• When A Piece Of A Continent Breaks Off	2	34 W 1231
• Which Way Is North?	3	34 W 1232
• Why Does Sea Level Change?	2-3	34 W 1233

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CEEP MODULE NO. MO10 6-6
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CRUSTAL EVOLUTION EDUCATION PROJECT

NAME DATE

Student Investigation

Catalog No. 34W1103

Crustal Movement: A Major Force In Evolution

INTRODUCTION

Fossils in rocks show that many different organisms lived in the geologic past. At times the fossils in rocks show that these organisms died out rather suddenly and were then replaced by new forms. What could have been the reason for such rapid changes?

Charles Darwin published a book *On The Origin Of Species* in 1859. This book explained Darwin's theory of how **evolution** occurred. The theory of evolution explains the stages and forms of development that animals and plants have gone through during geologic time. The **fossil record** supports the theory of evolution. The fossil record shows the remains or traces of once-living organisms found in sediments. However, the fossil record does not show how evolution works. Darwin said that evolution is caused by changes in the environment. When the environment changes, it puts stress on the organisms. Over a period of many generations the organisms either adapt to the change in the environment or die out. When *all* of one kind of organisms dies, it is called **extinction.**

In the fossil record, earth scientists can see periods of relatively rapid evolution, then periods of extinctions followed by rapid evolution. Such relatively rapid changes in the fossil record present a problem. No one knows the reason for these changes. Such things as river floods, volcanic eruptions or earthquakes are too local and short-lived to be the cause. There must be a much greater or even worldwide force for evolutionary change. What can that force be?

OBJECTIVES

After you have completed these activities, you should be able to:

1. Determine the rate of crustal plate movement during periods of geologic time.
2. Interpret areas that represent flooding and draining of continents, using a graph of sea level changes.
3. Determine the effects of sea level change on evolution and extinction.
4. Describe the relative amount of stress and former environmental conditions that existed at the time the sediments were deposited, using a model "rock column."

SE 038 138

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PROCEDURE

PART A: How fast do ocean plates move?

Materials: metric rulers

In a previous activity you may have learned how the rate of sea-floor spreading is believed to affect sea level. During times of rapid plate movement, the mid-ocean ridges swell upward and outward, causing a rise in sea level. In times of little or no plate movement, the ocean ridges sink and sea level falls.

1. Figure 2 shows the distance the North American plate and the African and Eurasian plates spread apart during the past seven intervals of geologic time. Complete Worksheet 1 to determine what interval of time had the most active plate movement. Metric rulers must be used on Figure 2; 1 cm = 1000 km.

2. During what interval of geologic time did the Atlantic Ocean begin to open?

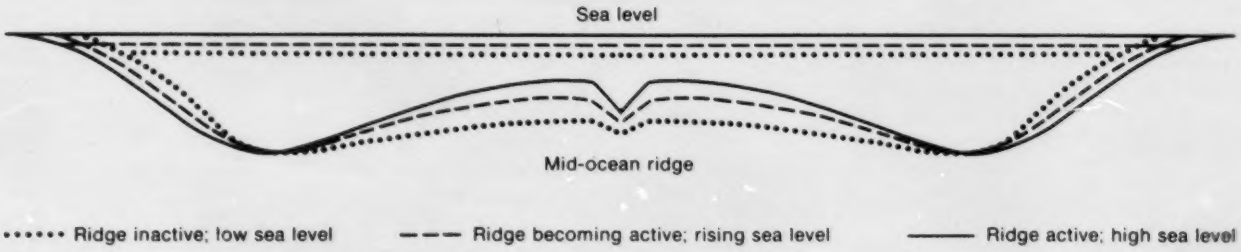

Sea level
Mid-ocean ridge
Ridge inactive; low sea level
Ridge becoming active; rising sea level
Ridge active; high sea level

Figure 1. Swelling along the mid-ocean ridge causes a rise in sea level.

By determining the age of sediments, scientists have been able to measure the distance plates have moved during various periods of geologic time.

3. During which of the intervals of geologic time was the slowest plate movement?

4. During which of the intervals of geologic time was the fastest plate movement?

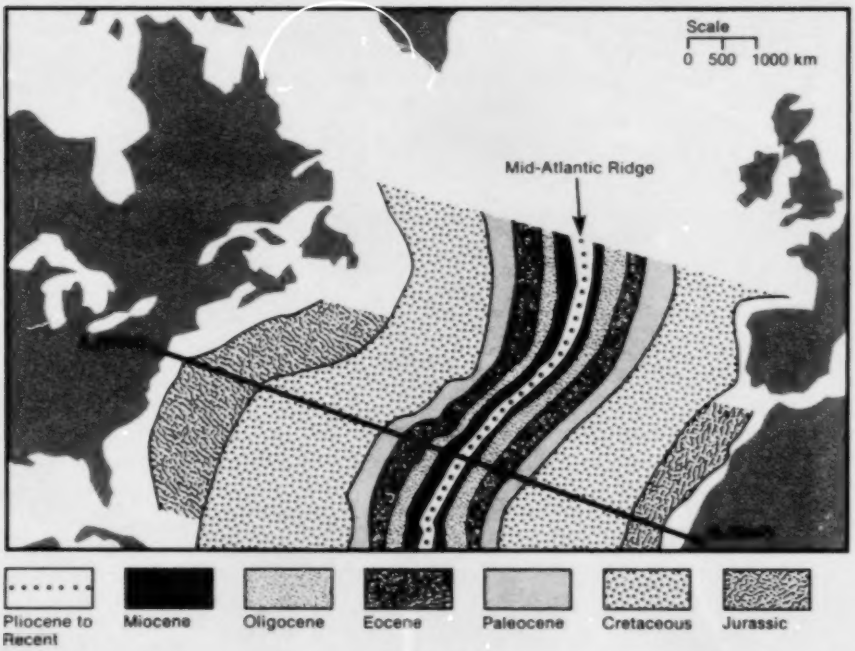


Figure 2. Map showing the distances crustal plates have moved away from the Mid-Atlantic Ridge during the past 190 million years. (Modified from Lamont-Doherty Geological Observatory, Columbia University, 1974.)

Rate of Movement of Crustal Plates Along the Mid-Atlantic Ridge

Column No. 1	2	3	4	5	6	7
Geologic time interval	Duration of geologic time interval in millions of years (from col. 1)	Amount of movement measured along line A–B during geologic time intervals			Average rate of movement in a *million* years:	Average rate of movement in *one* year Remember: 1 km = 100,000 cm
		West of ridge	East of ridge	Average: col. 3 + 4 ÷ 2	col. 5 ÷ col. 2	
Youngest						
Pliocene to Recent 0–5 m.y.a.	5 m.y.	100 km	100 km	100 km	20 km/m.y.	2.00 cm/yr
Miocene 5–23 m.y.a.	18 m.y.				km/m.y.	cm/yr
Oligocene 23–38 m.y.a.	15 m.y.				km/m.y.	cm/yr
Eocene 38–53 m.y.a.	m.y.				km/m.y.	cm/yr
Paleocene 53–65 m.y.a.	m.y.				km/m.y.	cm/yr
Cretaceous 65–135 m.y.a.	m.y.				km/m.y.	cm/yr
Oldest						
Jurassic 135–180 m.y.a.	m.y.				km/m.y.	cm/yr

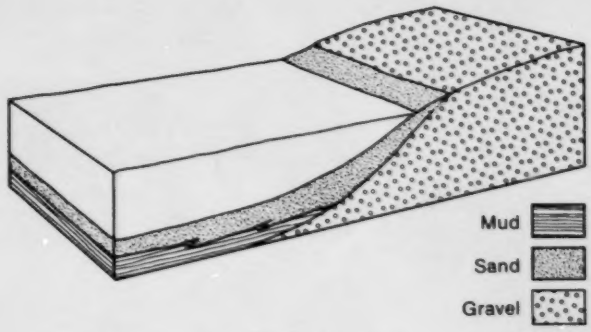
Worksheet 1 (PART A)

As you have seen, the Cretaceous Period was a time of active plate movement. This movement was not always continuous and steady but occurred in "spurts". There were times of rapid plate spreading and ocean ridge building and swelling. There were also quiet times when plate movement slowed and ocean ridges contracted. Geologists have identified at least nine major rises and falls of sea level by studying ocean sedimentation patterns that occurred during the Cretaceous Period.

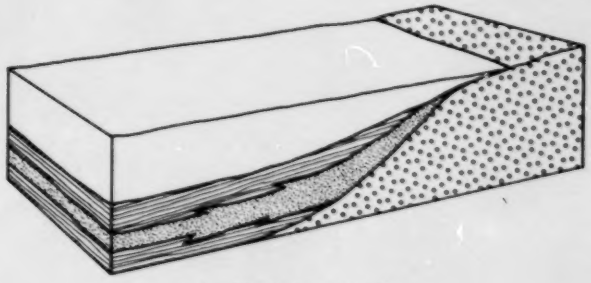
5. Look at the graph in Figure 4. Write the word "rising" on the graph where the line shows sea level rising. Write the word "falling" on the graph where the line shows sea level falling.

6. Did the sea level rise or fall during times of rapid plate movement?

7. Did the sea level rise or fall during times of slow plate movement?



a. Low sea level



b. High sea level

Figure 3. Sedimentation pattern for high and low sea level today.

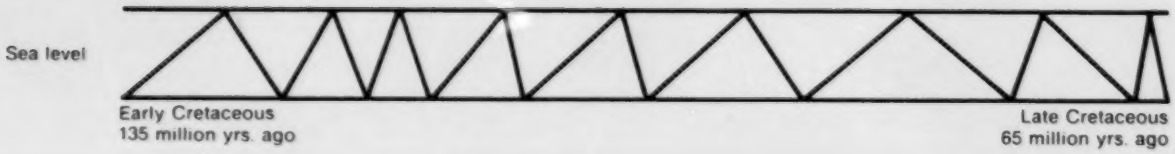


Figure 4. Graph shows the rise and fall of sea level during the Cretaceous Period.

PROCEDURE

PART B: How does the change in sea level affect the organisms?

Materials: metric ruler

You have seen how movement of the crustal plates away from the ocean ridges is believed to have caused changes in sea level. Not only was the appearance of the earth's surface affected, but sea level shifts also caused great changes in world climates.

During times of higher sea levels, coastal plains and inland depressions became shallow seas. Changes in the seasons became more moderate. Higher sea levels produced a more uniform, warm and moist climate. (See Figure 5.)

Lower sea levels drained coastal and inland seas. More land area was exposed and there were changes in ocean currents which distribute heat around the world. A cooler and drier climate resulted. (See Figure 5.)

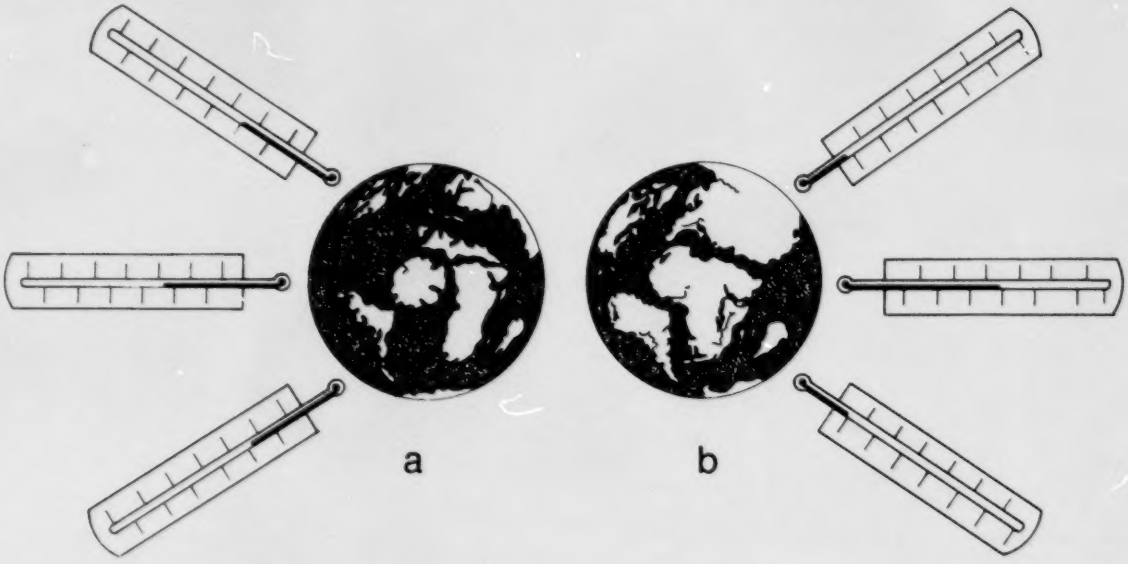


Figure 5. Changes in the sea level can (a) flood or (b) drain the continents, creating moderate or extreme climates.

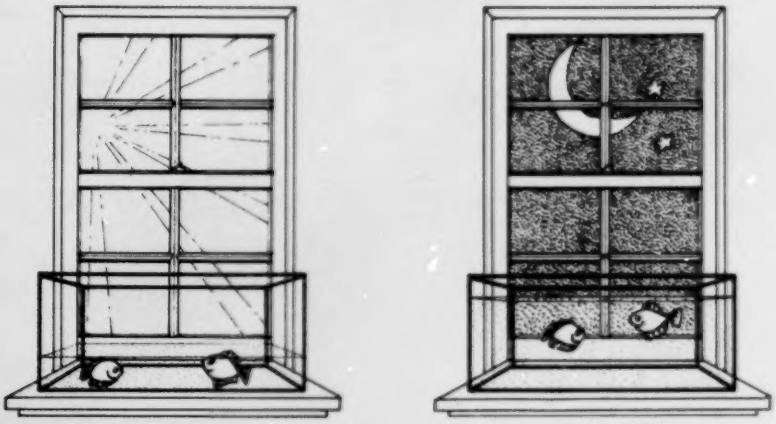
Changes in sea level and climate caused stress on the organisms that lived in the oceans. To help understand the idea of **environmental stress,** think of the following situation:

You have two fish tanks. One fish tank you keep on a window ledge. The water gets quite warm during the day when the sun is shining in, and it gets cool at night because it is close to the window. Also, you allow the water level to get very low, and then you fill the tank to the top. You are allowing the water level to change constantly. (See Figure 6.)

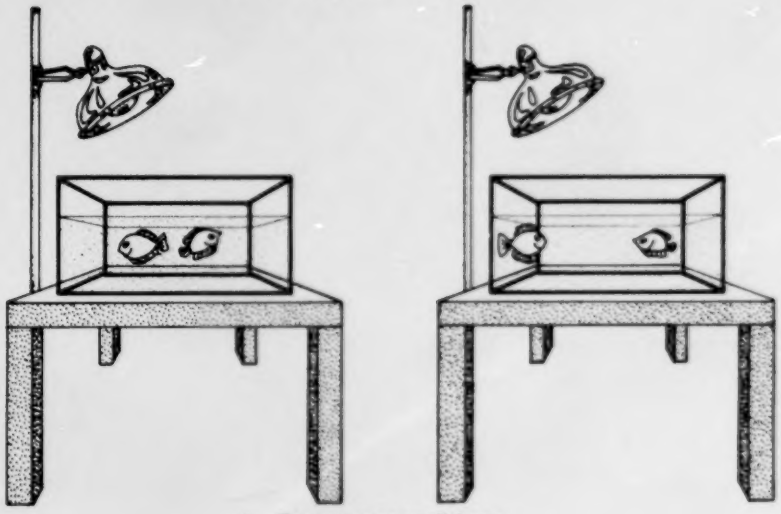
The other fish tank you keep in the center of the room. It always gets the same amount of light, and it stays at a comfortable room temperature throughout the year. You are careful not to allow too much water to evaporate before you bring it back up to level. (See Figure 6.)

1. Which tank involves more stress on the organisms?

2. Which tank will have the more stable environment?



a. Changeable conditions.



b. Constant conditions.

Figure 6. Environmental conditions

Recent studies have shown that there is a link between evolution and environmental stability.

Cephalopods (sef'-uh-la-pahds) are marine organisms that were common in the ocean during the Cretaceous Period. See Figure 7. The graph in Worksheet 2 shows the number of cephalopod groups that came into existence during the Cretaceous Period. This graph is called an **origin curve.** The drawing at the top of this graph shows how the sea level was changing during this time.

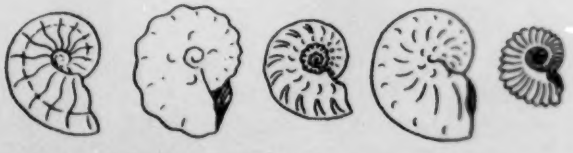
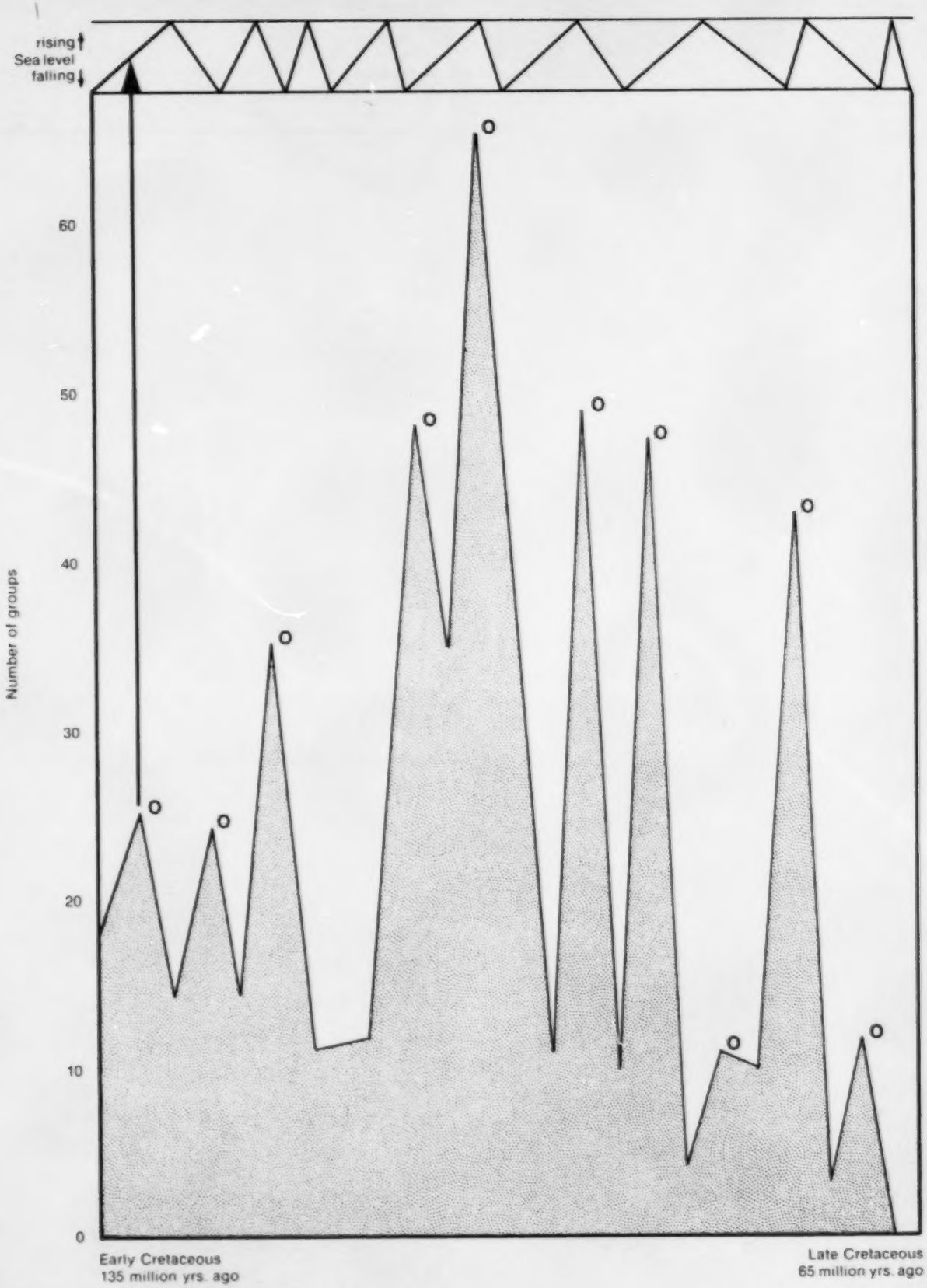


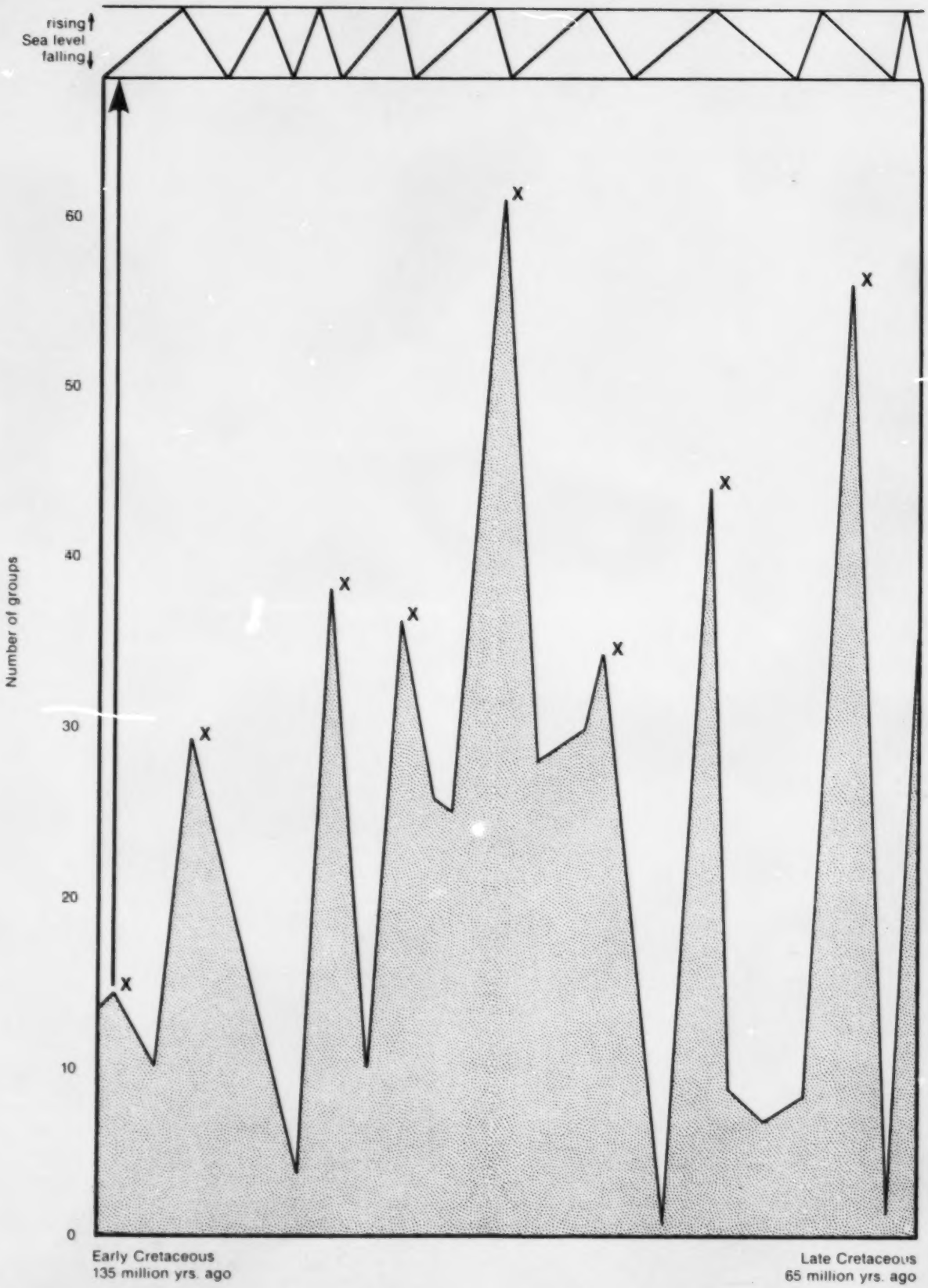
Figure 7. Cephalopod shells

Draw a straight line from each peak marked "O" on the origin graph upward to the sea level line. (Make certain that your straight lines are parallel to the first solid line that has already been drawn.)

3. When do most of the peaks in the origin curve occur, during sea level *rise* or sea level *fall*?



This origin curve graph shows the number of cephalopod groups that came into existence during the Cretaceous Period. The line graph at the top shows the sea level changes during this time. (Modified from Kaufman, 1976.)



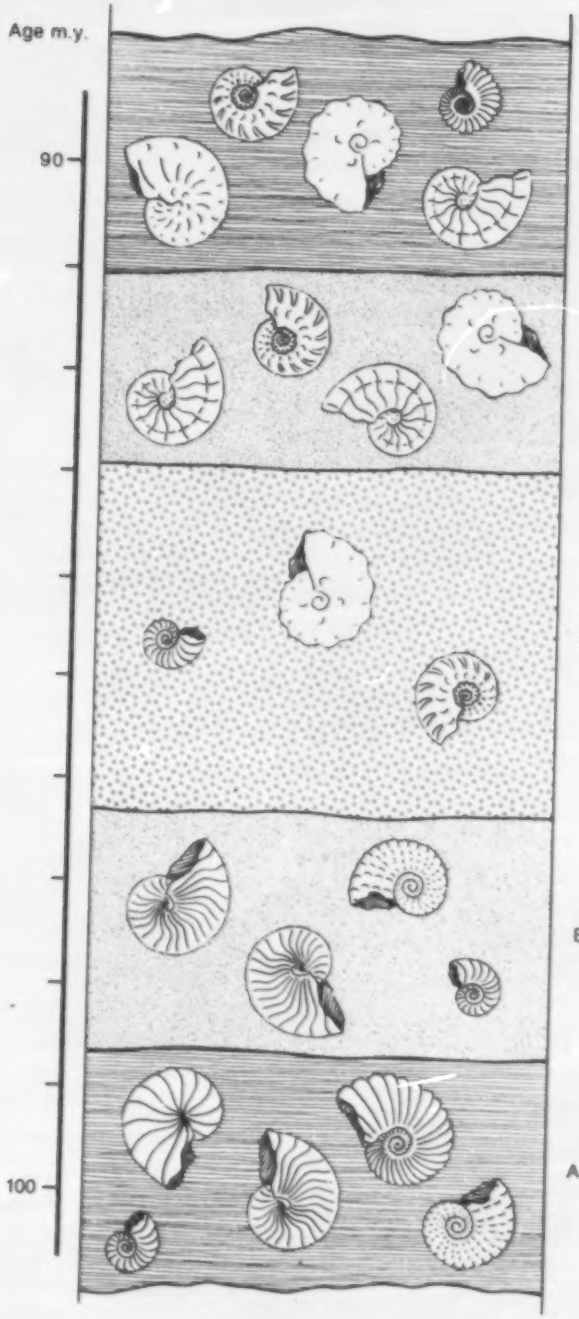
This extinction curve graph shows the number of cephalopod groups that became extinct during the Cretaceous Period. The line graph at the top shows the sea level changes during this time. (Modified from Kaufman, 1976.)

Worksheet 3 (PART B)

The graph in Worksheet 3 shows the number of cephalopod groups that became extinct during the Cretaceous Period. This graph is called an **extinction curve.** Draw a line from each peak marked "X" on the extinction curve upward to the sea level line. Again, make certain that these lines are parallel to the first line that has been drawn.

4. Do most of the peaks in the extinction curve occur during sea level rise or sea level fall?

5. How do you think the origin and extinction of the cephalopods are related to sea level changes? (Spend some time thinking of all possibilities.)



Rising sea level or falling sea level (Start at unit A)

High environmental stress or low environmental stress

E _____ _____

D _____ _____

C _____ _____

B _____ _____

Worksheet 4 (PART B)

Worksheet 4 shows a model of a column of sediment that was deposited during the Cretaceous Period. The oldest layer is at the bottom; the youngest layer is at the top.

From the fossils and the type of sediment, you can tell much about the environment during the time the sediments were deposited.

6. From what you have learned in this activity, label each sediment unit on Worksheet 4 as representing sediment deposited during either rising or falling sea level. Start at the bottom unit, A, and work upward to E. (Also see Figure 3.)

7. From what you have learned in this activity, label each sediment unit as showing a period of either high or low environmental stress for the organisms.

8. Which sediment units show increasing rate of extinction?

9. Which sediment units show increasing rate of evolution?

SUMMARY QUESTIONS

1. Explain how sea level changes can be caused by crustal movement.

2. Explain how changes in sea level can affect worldwide climatic conditions.

3. Explain how crustal movement could be a worldwide force for evolutionary change.

REFERENCE

Kaufman, E.G., 1976, Plate tectonics: major force in evolution. *The Science Teacher,* v. 43, no. 3 (Mar.), p. 12–17.

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